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US 5643476 A **US 5151134 A**
US 4368080 A

(58) Field of Search
UK CL (Edition V) **A4F**
INT CL[7] **E01H, E04G**
Other: **Online: WPI, EPODOC, PAJ**

(54) Abstract Title
Method and apparatus for removing chewing gum from a surface

(57) The method comprises directing abeam of laser energy at the offending gum at an energy level sufficient to soften it, the laser beam having a width of 5-30 mm. directing a jet of gas at the softened gum to remove it from the surface, and applying suction in the region of the gum to take it away from the surface. The laser is preferably an HDPL, an Nd:YAG or a CO_2 laser of average powerless than 500W, preferably 20-70W. The apparatus comprises a laser, gas jetting means and suction means suitable to carry out the above steps. The apparatus preferably comprises a trolley for movement across a surface to be treated, where 58 is a conduit for the jetting gas, 62 is a suction conduit and 60 is the laser. A skirt 66 surrounds the immediate area being treated to contain the dislodged gum.

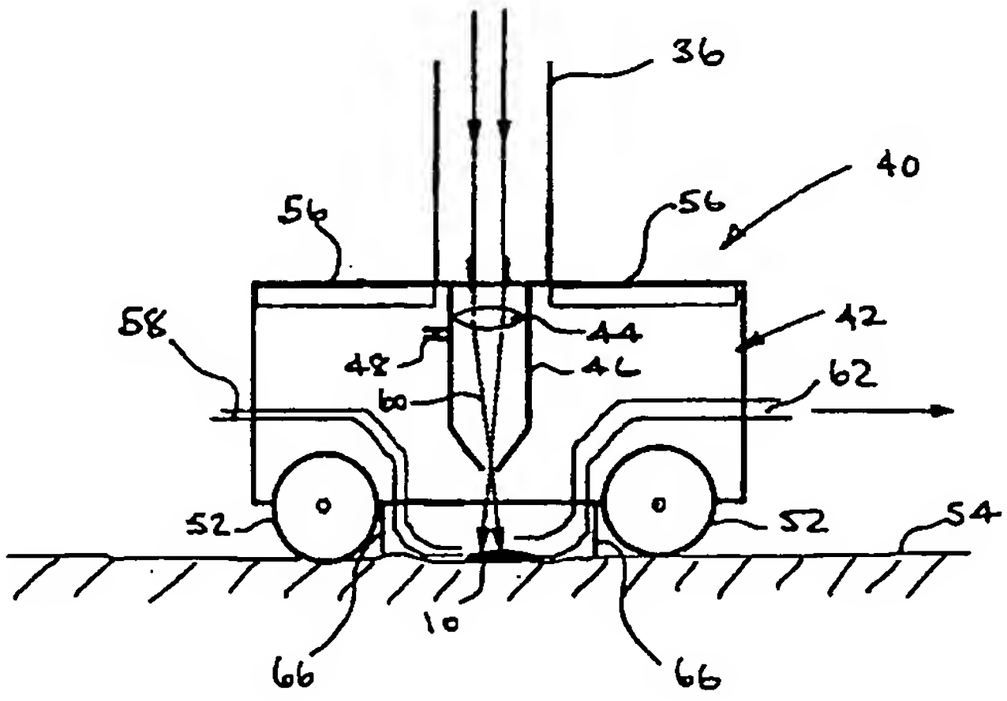

Fig. 3

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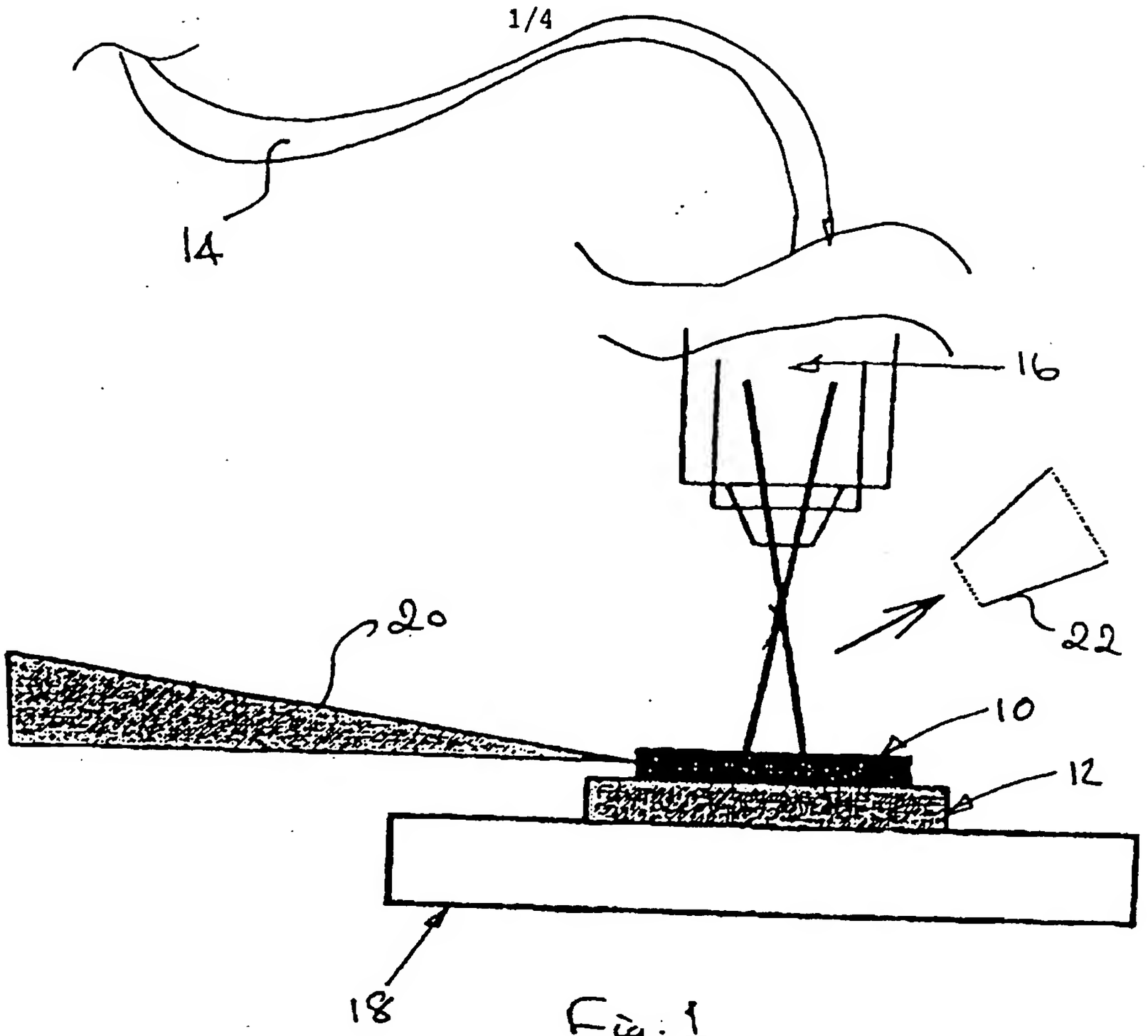
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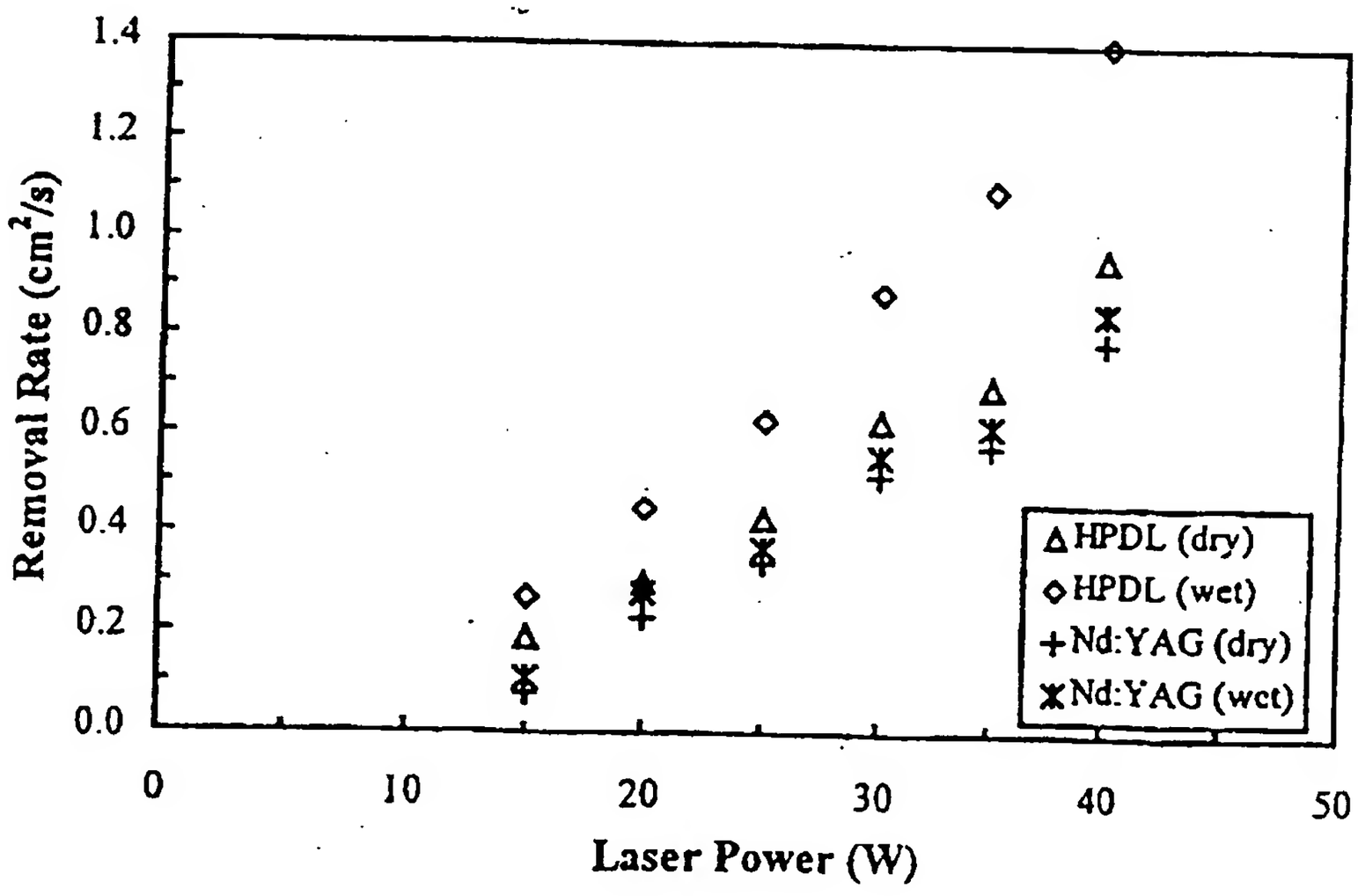
Fig. 1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1.2
1.0
0.8
0.6
0.4
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0
10
20
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40
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Laser Power (W)
HPDL (dry)
HPDL (wet)
Nd:YAG (dry)
Nd:YAG (wet)

Fig. 5

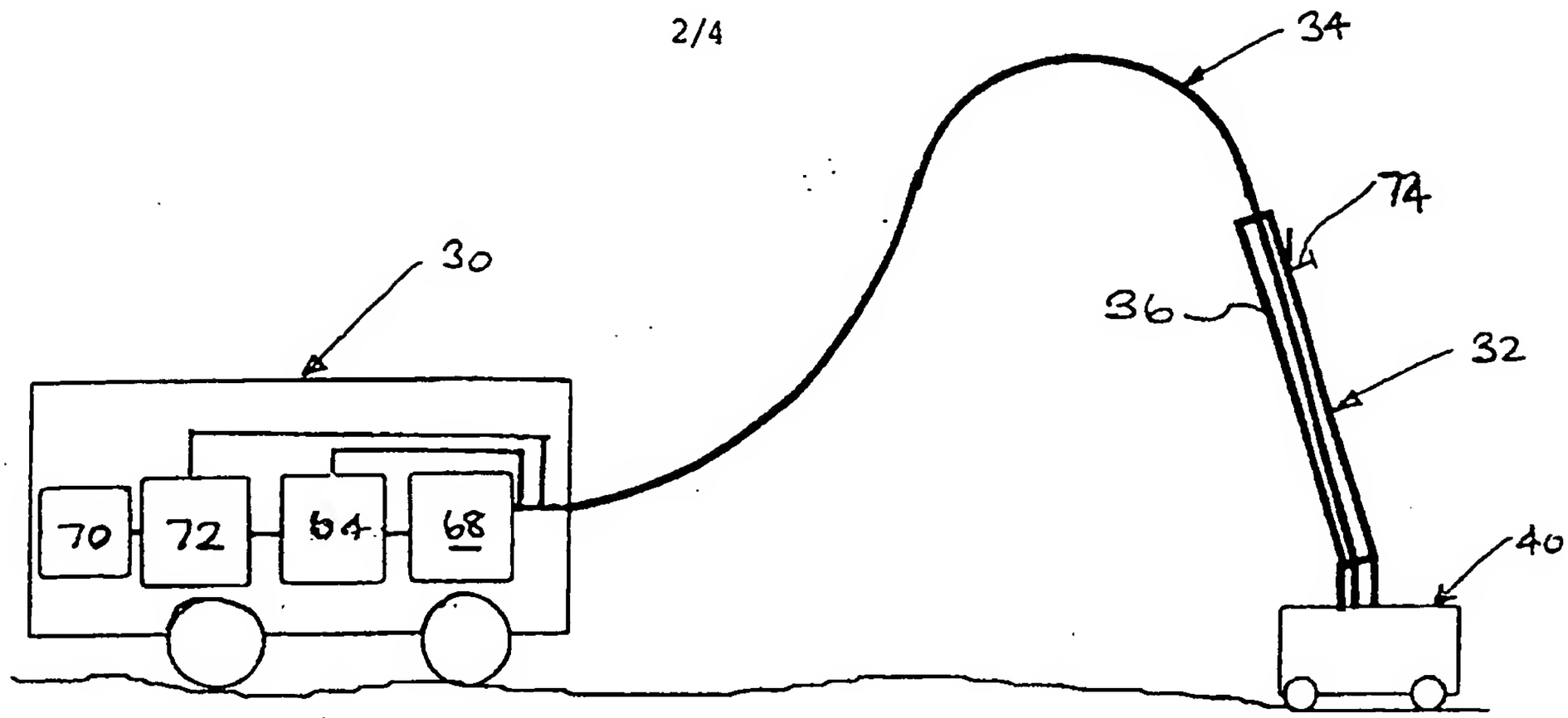
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Fig. 2

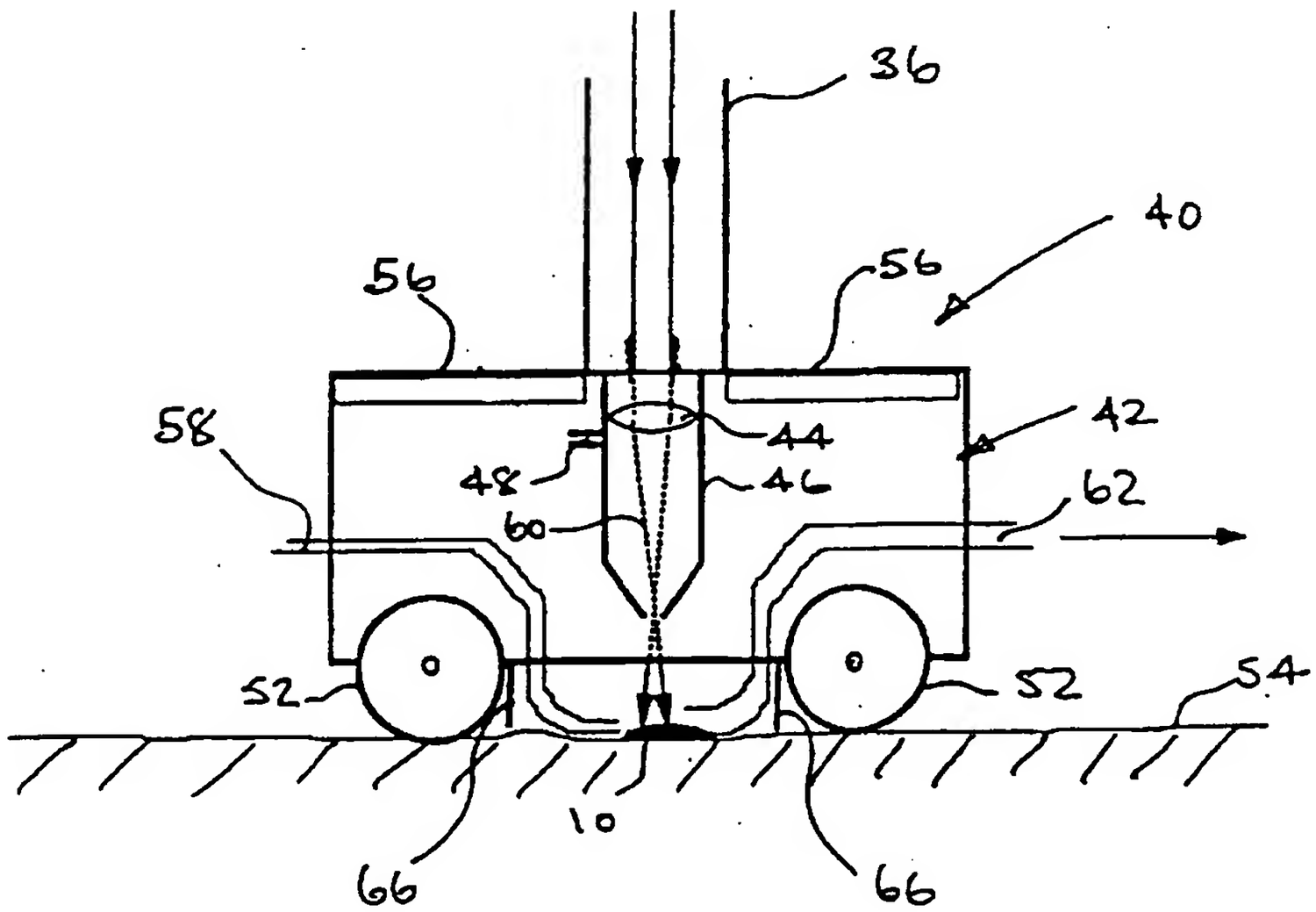
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Fig. 3

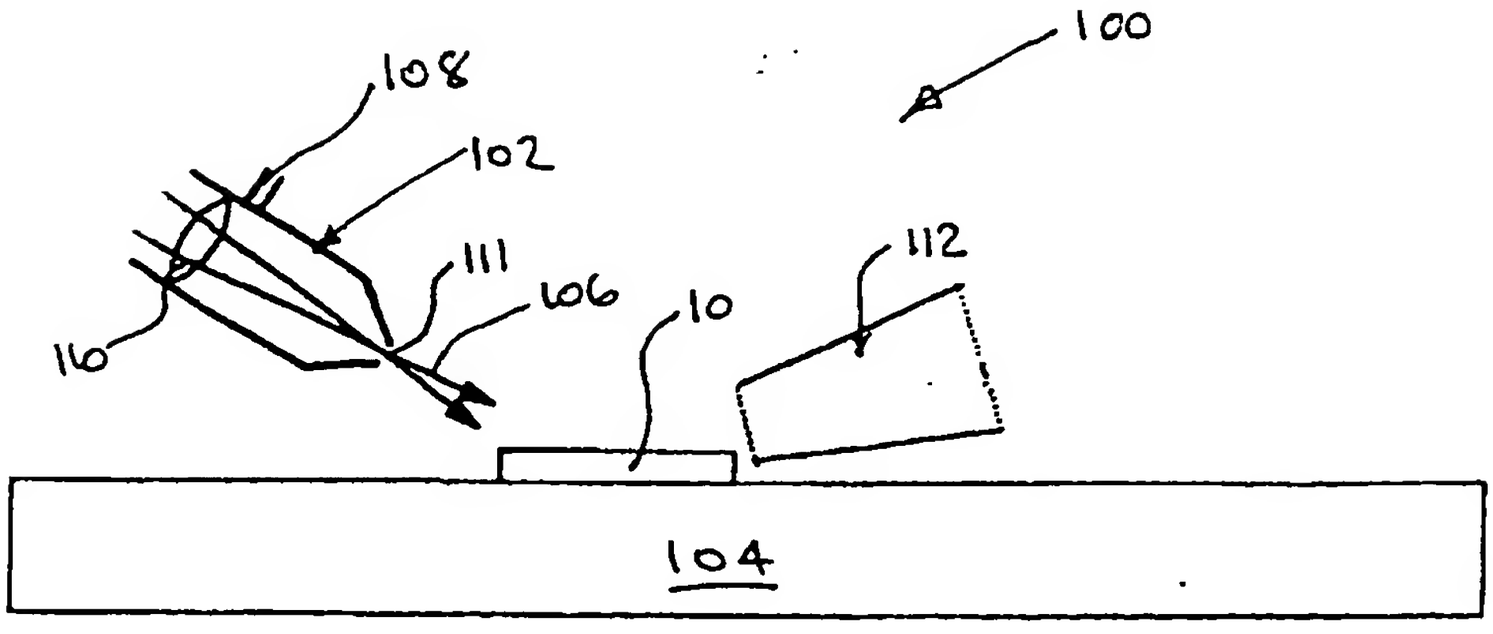

Fig. 4.

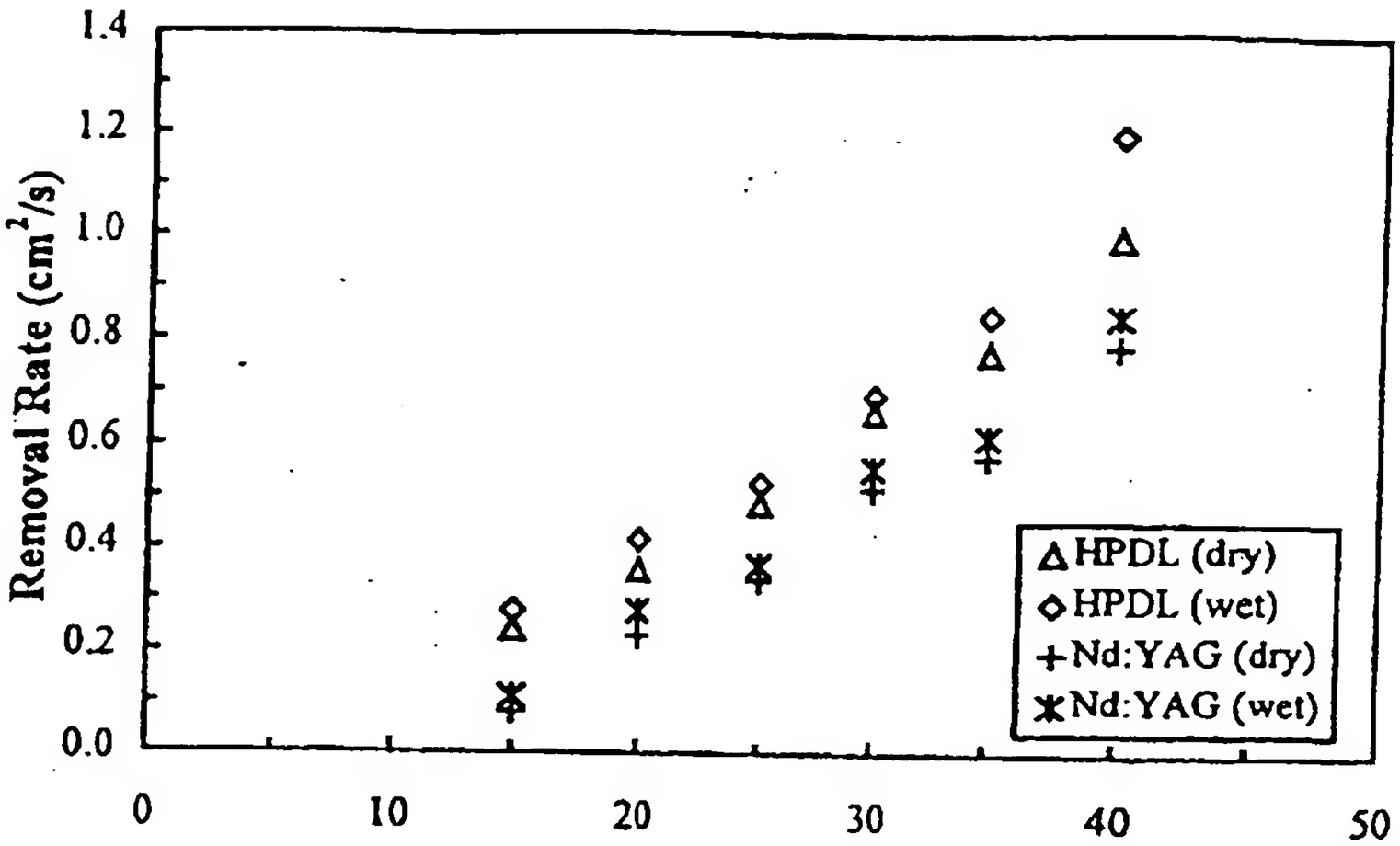
Removal Rate (cm²/s)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
Laser Power (W)
HPDL (dry)
HPDL (wet)
Nd:YAG (dry)
Nd:YAG (wet)

Fig. 6

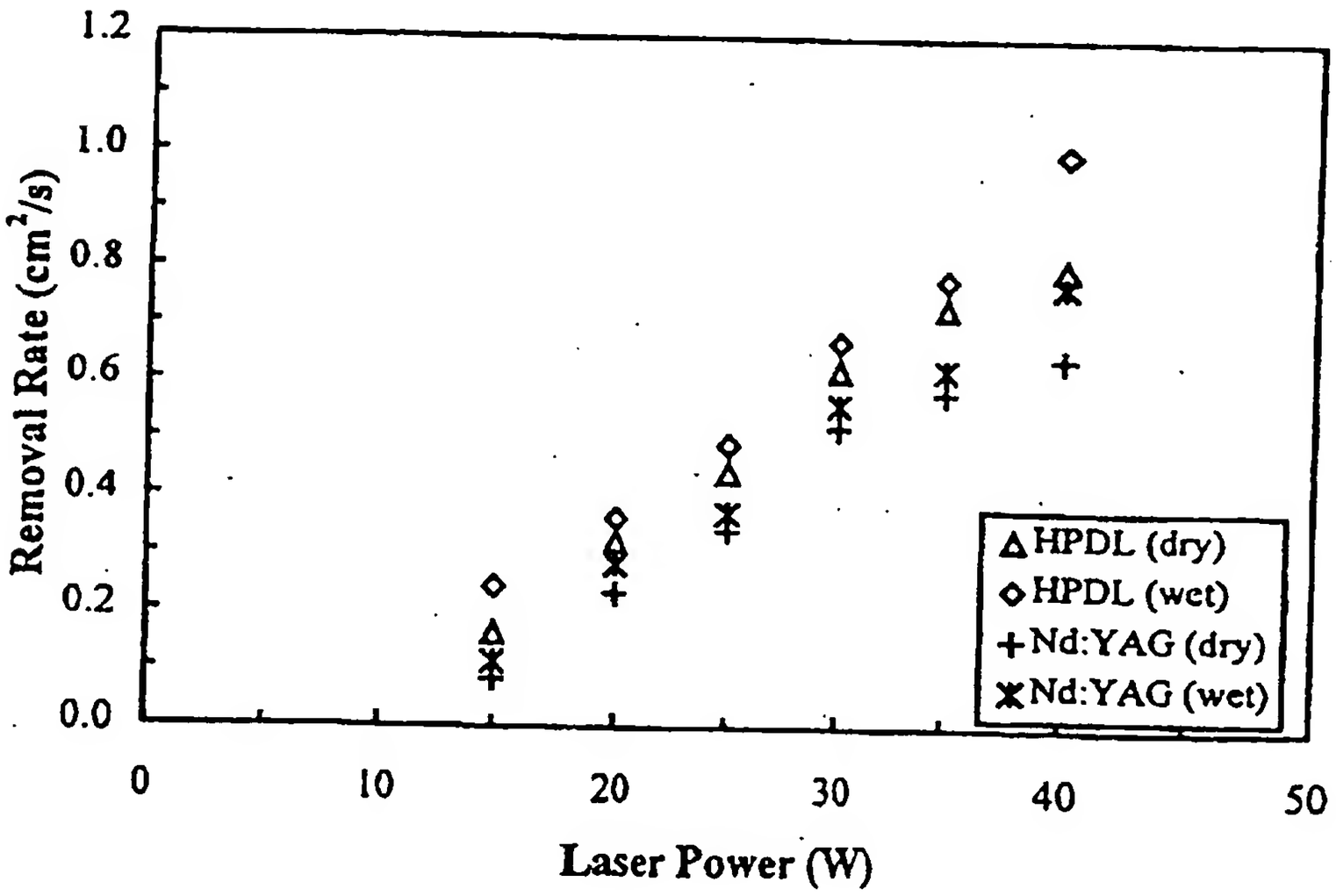
Removal Rate (cm²/s)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
Laser Power (W)
HPDL (dry)
HPDL (wet)
Nd:YAG (dry)
Nd:YAG (wet)

Fig. 7

A METHOD AND APPARATUS FOR REMOVING GUM

The present invention relates to the removal of chewing gum from surfaces.

The removal of chewing gum from, for example, public places is a serious problem. A survey in 1998 estimated that in the United Kingdom alone, some 13 million sticks of chewing gum are chewed each day. It is further estimated that local government councils in the UK spend more than £100 million each year removing gum from public areas.

Various methods have been employed to remove chewing gum.

Physical scraping has been used but this method is inadequate on rough surfaces and can cause damage to the surface.

Chemicals have been used but these often also stain and damage surfaces and regulations relating to environmental considerations forbid such chemicals from being washed down drains. JP-A-06142621 describes chemical removal techniques.

Cold air techniques and liquefied gases described in DE-A-2553944 have been used to freeze the gum and permit disintegration. However, this technique leaves an oil

deposit on the surface and is quite energy intensive and time consuming.

High pressure hot and/or cold water jets have been used but this method is messy and can also damage surfaces and the surrounding area. DE-A-23531185 describes such techniques.

International patent application, publication number WO 98/00608 describes the use of superheated steam at about 180°C for the removal of chewing gum. However, only a limited amount of water can be carried in the apparatus described and a lot of energy is needed to heat the water. The method is also relatively slow in dealing with individual pieces of gum adhered to the ground.

An object of the present invention is to provide an efficient and economic method and apparatus for the removal of chewing gum from a surface without damaging the surface.

According to a first aspect of the present invention there is provided a method of removing chewing gum from a surface, the method comprising the steps of directing a beam of laser energy at a piece of chewing gum of an energy level sufficient to change the gum from a solid dense form to a softer form, the laser beam width lying in the range of 5 to 30mm directing a jet of gas at the gum to impinge on the gum to remove it from the surface and applying suction/a vacuum to collect the gum detached from said surface by said gas jet.

In the case of laser produced energy it was previously thought that sufficient power to cause ablation or vaporisation of the chewing gum would be needed. Power levels of about 1KW were predicted as being required thus making any laser based removal method both energy intensive and potentially very dangerous when used in public places. However, we have discovered that such high power levels are not required since ablation or vaporisation is unnecessary. We have found that some types of laser radiation couple efficiently with the chewing gum and induce a change of state. The physical nature of the gum is changed from a hard, dense form to a softer form which may be easily blown from the surface by, for example, a jet of compressed air and collected by, for example, vacuum means. Furthermore, instead of high powers in the region of 1KW, power levels below 500W and even below 100W have been found to be entirely adequate in producing this change of state. Generated temperatures in the region of 190°C were produced in the gum and which caused no damage to the substrate to which gum samples were adhered.

We have further found that certain types of laser have the desired characteristics in coupling with the gum to effect the above described change of state. Preferably, the laser device may be a high-power diode laser (HPDL), a Nd:YAG laser or a carbon dioxide laser. If excessive power densities are applied we have found that carbon dioxide lasers cause charring of the gum and consequent damage to the substrate.

The gas jet may comprise any suitable gas such as compressed air, nitrogen or carbon dioxide for example.

It has been found that the method of the present invention is effective in removing gum from ordinary Portland cement (OPC), concrete paving slabs, clay bricks and marble tiles. These materials were the only ones used in tests and there is no reason to think that other substrates would not be treated equally effectively.

In one example of the present invention using a HPDL laser, an average power of 40W and a beam width of 12mm were used to remove gum from an OPC substrate. A traverse speed of 8mm/s was employed to effect removal with simultaneous compressed air jet. Thus a power density of approximately 0.4W/mm^2 is adequate to effect removal. The rate of removal may be increased by increasing the power density and the traverse speed.

The preferred average laser power lies in the range of 20 to 70W and the preferred laser beam width in the range of 8 to 14mm.

The method of the present invention may also include the step of wetting the gum prior to treatment with the power source as this has been found to increase the rate of removal thereof. In the case of the example quoted above, when water is used to wet the gum, the beam width may be increased to 14mm and the traverse speed to 10mm/s whilst still maintaining an average power of 40W.

The preferred traverse speed of the beam lies in the range 5 to 20mm/s and more preferably from 8 to 14mm/s.

A parameter influencing the effectiveness of gum removal is the thickness thereof. However, most gum on ground surfaces tends to be trodden down to a relatively thin and

constant thickness.

The cure time of the gum, i.e. how long it has been on the surface appears to have little or no significant effect on removal efficiency.

According to a second aspect of the present invention there is provided chewing gum removal apparatus for the removal of chewing gum from a surface, the apparatus comprising a source of laser energy emitted at a level sufficient to change the gum from a solid dense form to a softer form, means for directing a beam of laser energy at the chewing gum, the laser beam width lying in the range of 5 to 30mm means to provide and direct a gas jet to impinge on the chewing gum and suction/vacuum means to collect chewing gum detached from said surface by said gas jet.

The direction of the gas jet may be such as to remove the gum from the surface to which it is adhered and may range from a position approaching normal to the surface to a position approaching parallel to the surface.

The direction of the gas jet may range from generally transverse to the laser beam direction to generally parallel thereto.

Where the gas jet is substantially parallel to the direction of the laser beam, it may also be used to cool and keep the laser beam focusing lens free of contaminants.

The apparatus may also include means to collect chewing gum detached from said surface by said gas jet.

The means for producing said optical radiation may preferably be an HPDL, a Nd:YAG laser or a carbon dioxide laser.

The laser beam may preferably be directed on to the chewing gum through an optical fibre where appropriate.

The laser may be housed in trolley or cart means preferably having a self contained generator which may also power a compressor to provide a source of compressed air to direct at the treated gum. The working part of the apparatus may comprise hand held or hand guided lance means connected to the trolley by an optical fibre. The lance may also be provided with a safety enclosure at its working end having appropriate safety switching to ensure that the laser can only be activated when the beam is pointing at the surface, usually the ground, which is to be cleaned. The safety enclosure may also incorporate gas jets fixed at a desired orientation relative to the surface being treated. An umbilical cable connecting the trolley and lance may also include gas supply pipes and electrical control cables. The trolley may also include means such a suction/vacuum means to recover the gum once detached from the surface by the gas jets.

In a more sophisticated apparatus, the component parts may be included into a wheeled device analogous to the familiar pavement and public area sweep cleaners used by local councils and operated by a ride-on driver or a person walking behind for example. Apparatus of this type may include a scanning system to identify locations where gum needs to be removed. Such locations may be identified by an on-board image recognition system for example. The apparatus would then either automatically locate itself

over the gum site or be manually positioned. In view of the fact that gum sites tend to be of relatively constant area, the laser beam may be automatically scanned across an area which would encompass the gum periphery and perform a blowing and recovery cycle automatically.

In order that the present invention may be more fully understood, examples will now be described by way of illustration only with reference to the accompanying drawings, of which:

Figure 1 shows schematic side elevation of test sample experimental set-up used in experiments;

Figure 2 shows a schematic side elevation of apparatus according to the present invention;

Figure 3 shows the operating laser head of Figure 2 in more detail;

Figure 4 shows a side elevation of a schematic second embodiment of apparatus according to the present invention;

Figure 5 shows a graph of gum removal rate by HPDL and Nd:YAG lasers vs laser power on OPC;

Figure 6 shows a graph of gum removal rate by HPDL and Nd:YAG lasers vs laser power on concrete paving slab material; and

Figure 7 which shows a graph of gum removal rate by HPDL and Nd:YAG lasers vs laser power on clay brick material.

Experiments were conducted using a commercially available brand of chewing gum, chewed under standard conditions as far as practicably possible and then applied to various substrate materials and treated with different types of laser devices as described below.

The chewing gum used was Wrigley's Airwaves (RTM). It was chewed on average for two hours before being applied to the substrates. The samples were then subjected to typical field conditions by placing them in the open air and walked on repeatedly. The average thickness of the chewing gum after subjection to field conditions was around 1mm, whilst the average area was about $4cm^2$.

The substrates chosen for the study were ordinary Portland cement (OPC), concrete paving stones, clay bricks and a grey marble tile. For experimental purposes the substrates were cut into squares of 100mm x 100mm, with typically four pieces of the chewing gum being applied to each square.

The lasers used were a CO_2 made by Rofin Sinar Gmbh, a surgical HPDL made by Diomed Ltd and a 400 W Nd:YAG laser made by Electrox Ltd. The operating characteristics of the lasers are detailed in Table 1 below.

Table 1.

Operating Characteristic	Laser		
	CO2	Nd:YAG	HPDL
Lasant	CO2	Nd:YAG Crystal	GaAIAs
Wavelength	10.6µm	1.06µm	810±20µm
Maximum Average Output	1 kW	400 W	60 W
Maximum Pulse Energy		70 J	
Pulse Width	100µm	0.3-10ms	-
Repetition Rate	1-1000Hz	1-1000Hz	-
Fibre Core Diameter	-	600µm	600µm
Mode of Operation	CW	Pulsed (rapid)	CW

Figure 1 shows a schematic view in elevation of the experimental set-up used for the tests described above. For the HPDL laser, the beam was delivered to the chewing gum sample 10 on the substrate 12 by means of a 4m long, 600µm core diameter optical fibre 14, the end of which was connected to a 2:1 focusing lens assembly 16 mounted on the z-axis of a 3-axis CNC gantry table 18. In the case of the Nd:YAG laser, the beam was delivered via a 5m long, 600µm core diameter optical fibre which in this case was connected to a 120mm focal length lens 16. The CO_2 laser was delivered to the sample 10 by means of fixed lenses and mirrors (not shown) focused using a 200mm focal length lens. The samples 10 were irradiated using the defocused beams of each laser with spot diameters ranging from 3 to 14mm diameter and laser powers of 20 to 70W. The chewing gum sample 10 was irradiated by traversing the sample 10 on the CNC table 18 at traverse speeds ranging from 5 to 20mm/s, whilst 25 l/min of air was blown coaxially through the lens assembly 16, to shield the laser optics from fume and

debris, and transversely 20 to assist removal of the irradiated sample 10. Vacuum extraction 22 was provided to remove debris from the irradiated sample 10.

To analyse the chewing gum removal process in terms of generated temperatures, thermocouples were inserted beneath the chewing gum samples in contact with the substrate surface. For experimental purposes OPC was selected as the substrate during the temperature monitoring experiments. The thermocouples used were type-K class 2, with an accuracy of ± 2.5°C. To obtain accurate temperature readings, the thermocouples were attached to digital thermometers, with the thermometer readings being recorded along with the interaction times. The chewing gum samples were irradiated in the manner described above.

In the case of OPC, experiments were conducted with chewing gum samples that were dry and also coated with a water layer. Removal only proved possible with the HPDL and the Nd:YAG laser. With the water layer present, faster rates of removal could be achieved. The optimum HPDL and Nd:YAG laser removal parameters are detailed in Table 2 below. To avoid damage to OPC substrate the Nd:YAG laser parameters were manipulated to yield an average power of 40W (peak power of 2 kW a pulse width of 0.3 ms and a pulse frequency of 67 Hz).

Table 2

Laser Parameter	HPDL		Nd:YAG	
	Dry	Wet	Dry	Wet
Maximum Beam Spot Diameter	12mm	14mm	8mm	8mm
Power (Ave.)	40 W	40 W	40 W	40 W
Traverse Speed	8 mm/s	10 mm/s	10 mm/s	11 mm/s

There was no damage produced on the OPC substrate as a result of the HPDL removal process, and surface marks present before the application of the chewing gum were unaffected by the laser beam. This was also the case when using the Nd:YAG laser.

It is possible to quantify the chewing gum removal rate, and to determine the laser parameter scaling factors required to achieve a desired removal rate. In order to quantify the chewing gum removal rate fixed laser powers increasing from 20-40 W at regular intervals were used, whilst at the same time the laser beam spot diameter and the traverse speed were adjusted accordingly to achieve removal. The removal rate is expressed in cm^2/s according to the equation

$$r = (\phi - i)v \qquad (1)$$

where, r = Removal rate (cm^2/s)
i = Overlap (cm)
v = Traverse speed (cm/s)
ϕ = Beam diameter (cm)

Consequently it is possible to plot the removal rate against the laser powers for OPC as shown in Figure 5. As one can see, effectively there is no limitation on the attainable removal rate because as the laser power increases, then the laser beam diameter is increased

accordingly so as to avoid damage to the substrate. As the beam spot size increases so the area covered in one pass increases thus increasing the removal rate. It will be noted from Figure 4 that the maximum laser power indicated is still relatively very low at 50 W.

In the case of concrete paving slab material, experiments were conducted with chewing gum samples that. were dry and coated with a water layer. Again, removal only proved possible with the HPDL and the Nd:YAG laser. With the water layer, faster rates or removal could be achieved. The optimum laser removal parameters for the HPDL and the Nd:YAG laser are detailed in Table 3 below. To avoid damage to the concrete substrate the Nd:YAG laser parameters were manipulated to yield an average power of 40W (peak power of 2 KW a pulse width of 0.3ms and a pulse frequency of 67 Hz).

Table 3

Laser Parameter	HPDL		Nd:YAG	
	Dry	Wet	Dry	Wet
Maximum Beam Spot Diameter	10mm	10mm	8mm	8mm
Power (Ave.)	40 W	40 W	40 W	40 W
Traverse Speed	10 mm/s	12 mm/s	10 mm/s	11 mm/s

Figure 6 shows the relationship between chewing gum removal rate of the HPDL and Nd:YAG lasers and laser power for concrete paving slabs.

In the case of clay bricks, experiments were conducted with chewing gum samples that were dry and coated with a water layer. No discernible difference in the amount of

chewing gum removed from the clay bricks in dry or wet conditions was observed, with all of the chewing gum being removed under both conditions. Moreover, the vegetable oil stain was not present after removal. However, with the water layer faster rates of removal could be achieved. The optimum HPDL and Nd:YAG removal parameters are detailed in Table 4 below.

Table 4

Laser Parameter	HPDL		Nd:YAG	
	Dry	Wet	Dry	Wet
Maximum Beam Width	10mm	10mm	8mm	8mm
Power (Ave.)	40 W	40 W	40 W	40 W
Traverse Speed	8 mm/s	10 mm/s	10 mm/s	10 mm/s

Figure 7 shows the relationship between chewing gum removal rate of the HPDL and Nd:YAG lasers and laser power for clay brick substrates.

In the case of marble tiles, experiments were conducted with chewing gum samples that were dry and coated with a water layer. No discernible difference in the amount of chewing gum removed from the marble tiles in dry or wet conditions was observed. In both cases, only incomplete removal was achieved. Small particulates were left behind on the substrate, the volume being miniscule. However, the vegetable oil stain was not visible after removal under both dry and wet conditions. Again, with a water layer on the sample surface, faster rates of removal could be achieved. The optimum HPDL removal parameters are detailed in Table 5 below.

Table 5.

Laser Parameter	Dry Conditions	Wet Conditions
Maximum Beam Width	10mm	10mm
Power	40 W	40 W
Traverse Speed	11 mm/s	12 mm/s

In all cases, the chewing gum upon being irradiated by the HPDL and Nd:YAG lasers changed from a solid dense resilient material to a softer consistency which is modified by the compressed jet into a "fluffy" material that is blown to one side and collected.

Figures 2 and 3 show in schematic form apparatus for the removal of gum from public places for example and which could be operated by local government bodies or contractors for example. The apparatus comprises a trolley 30 which may be pulled by an operator (not shown) or have its own motive power such as an electric motor (not shown) for example; and, a hand-held lance 32 which may be manipulated by the operator, the trolley 30 and lance 32 being connected by an umbilical cord 34. The trolley carries the laser device 68 per se and either a mains power lead which may be plugged into a convenient power source, or an on-board generator 70 and a compressor 72. The lance 32 includes a hand-held, rigid conduit 36 of convenient length for the operator and through which run an optical fibre cable and gas supply and suction tubes which constitute the umbilical cord 34 and which also contains electrical control cables. At the bottom end of the lance 32 is a laser operating head assembly 40. The operating head comprises an enclosure 42

having a focusing lens 44 housed in a sleeve 46 through which may be passed compressed air via an inlet 48 in order to prevent fume and debris from reaching the lens 44. The enclosure 42 has wheels 52 which are in contact with suitable switches (not shown) such that a laser beam can only be turned on when the wheels are in contact with the ground 54. The enclosure has a window 56 in its upper face which is transparent to normal light but opaque to the wavelength of the laser light. A gas inlet conduit 58 for providing a gas jet generally transverse to the laser beam 60 and impinging upon the chewing gum 10 to be removed. A debris removal exhaust conduit 62 is provided through which collection can be effected by means of a flexible conduit as part of the umbilical cord 34 to vacuum means 64 in the trolley 30. Flexible skirts 66 are provided on the lower side of the enclosure to prevent escape of debris as far as possible. The lance 32 has hand operated switches 74 to initiate the laser, compressor and vacuum means in response thereto.

In operation, the enclosure 42 is sited over the chewing gum to be removed and the laser, compressor and vacuum means initiated by the switch 74, the enclosure being moved so that the entire area of the gum deposit is covered by the laser bean spot until removed.

Figure 4 shows a side view of a schematic arrangement 100 of a second embodiment of apparatus according to the present invention. In this embodiment, the laser delivery head 102 is angled obliquely to the gum 10 on the substrate 104. The laser head 102 has a gas supply 108 to

sweep across the surface of the lens 110 to prevent contamination and which gas supply also provides the gas jet exitting from the nozzle 111 to impinge upon the laser treated gum to effect removal towards collection device 112. In this arrangement, the laser beam and gas jet are both parallel and substantially coaxial. The various safety systems and devices as described with reference to Figures 2 and 3 may also be incorporated into this embodiment. For example, the lance 32 and enclosure 40 may be utilised in this embodiment.

Although all references above have been directed to the removal of chewing gum, the invention may be used for the removal of other types of gum and compounds of a similar nature.

CLAIMS

1. A method of removing chewing gum from a surface, the method comprising the steps of directing a beam of laser energy at a piece of chewing gum of an energy level sufficient to change the gum from a solid dense form to a softer form, the laser beam width lying in the range of 5 to 30mm directing a jet of gas at the gum to impinge on the gum to remove it from the surface and applying suction/a vacuum to collect the gum detached from said surface by said gas jet.

2. A method according to claim 1 wherein the laser energy is produced by an HPDL, a Nd:YAG laser or a carbon dioxide laser.

3. A method as claimed in claim 1 or claim 2 wherein the average laser power is less than 500W.

4. A method according to claim 1 or claim 2 wherein the average laser power lies in the range from 20 to 70W.

5. A method according to any one of the preceding claims wherein the laser beam width lies in the range from 8 to 14mm.

6. A method according to any one preceding claim wherein a traverse speed of the laser beam lies in the range from 5 to 20 mm/s.

7. A method according to claim 6 wherein the laser beam traverse speed lies in the range from 8 to 14 mm/s.

8. A method according to any one preceding claim

wherein the chewing gum is irradiated in the dry condition.

9. A method according to any one preceding claim from 1 to 7 wherein the chewing gum is wet when initially irradiated.

10. A method according to any one preceding claim wherein the laser beam and the gas jet are substantially parallel.

11. A method according to claim 11 wherein a gas supply to maintain a laser head clean also provides the gas jet via the laser head.

12. A method according to any one preceding claim from 1 to 8 wherein the laser beam and the gas jet are generally transverse to each other.

13. Chewing gum removal apparatus for the removal of chewing gum from a surface, the apparatus comprising a source of laser energy emitted at a level sufficient to change the gum from a solid dense form to a softer form, means for directing a beam of laser energy at the chewing gum, the laser beam width lying in the range of 5 to 30mm means to provide and direct a gas jet to impinge on the chewing gum and suction/vacuum means to collect chewing gum detached from said surface by said gas jet.

14. Apparatus according to claim 13 wherein the source of laser energy is selected from the group comprising: an HPDL laser; a Nd:YAG laser; and a carbon dioxide laser.

15. Apparatus according to claim 13 or claim 14 wherein the laser beam is directed on to the chewing

gum through an optical fibre.

16. Apparatus according to any one of claims 13 to 15 wherein the laser device is housed in a trolley and connected to an operating head via an optical fibre and hand-held lance means.

17. Apparatus according to claim 16 wherein said trolley also includes electrical generator means.

18. Apparatus according to either claim 15 or claim 16 wherein said trolley also includes gas compressor means.

19. Apparatus according to any one of preceding claims 15 to 17 wherein said lance means also has an enclosure at its working end having switching to ensure that the laser can only be activated when the beam is pointing at the surface.

20. Apparatus according to claim 19 wherein the enclosures also incorporates a gas jet fixed at a desired orientation relative to the surface being treated.

21. Apparatus according to any one of preceding claims 16 to 20 wherein an umbilical cable connecting the trolley and lance means also includes gas supply pipes and electrical control cables.

22. Apparatus according to any one of preceding claims 16 to 21 wherein the trolley also includes suction/vacuum means to recover the gum once detached from the surface by the gas jet.

23. Apparatus according to any one of preceding claims 13 to 22 wherein the laser beam direction and

the gas jet direction are generally transverse to each other.

24. Apparatus according to any one of preceding claims 13 to 22 wherein the laser beam direction and the gas jet direction are substantially parallel to each other.

25. Apparatus according to claim 24 wherein a gas flow used to maintain a laser head clean also provides the gas jet.

26. Apparatus according to claim 25 wherein the laser beam and the gas jet are substantially coaxial.

27. A method of removing chewing gum from a surface substantially as hereinbefore described with reference to the accompanying description and Figure 1; or Figures 2 and 3; or Figure 4 of the drawings.

28. Chewing gum removal apparatus for removing chewing gum from a surface substantially as hereinbefore described with reference to the accompanying description and Figure 1; or Figures 2 and 3; or Figure 4 of the drawings.

INVESTOR IN PEOPLE

Application No: GB 0126763.2
Claims searched: 1-28

Examiner: John Wilson
Date of search: 24 January 2003

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
A		US 5643476	Garmire et al - whole document
A		US 5151134	Boquillon et al - whole document
A		US 4368080	Langen et al - whole document

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[V]:

A4F

Worldwide search of patent documents classified in the following areas of the IPC[7]:

E01H; E04G

The following online and other databases have been used in the preparation of this search report:

Online: WPI, EPODOC, PAJ